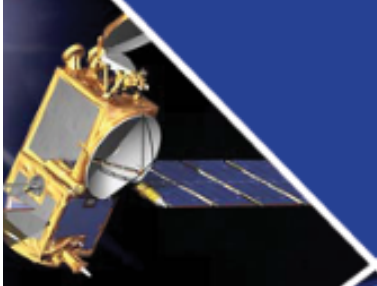
National Aeronautics
and Space Administration



2015

HEALTH & AIR QUALITY

NASA Earth Science
Applied Sciences Program

Health & Air Quality: 2015 Annual Summary

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I. Introduction

The ESD Applied Sciences Program promotes efforts to discover and demonstrate innovative and practical uses of Earth observations. The Program funds applied science research and applications projects to enable near-term uses of Earth observations, formulate new applications, integrate Earth observations and related products into practitioners' decision making, and transfer the applications. The projects are carried out in partnership with public- and private-sector organizations to achieve sustained use and benefits from the Earth observations.

The Applied Sciences Program's applications themes are currently focused on four of the nine Societal Benefit Areas (SBAs) of the interagency U.S. Group on Earth Observations (USGEO): Health (including Air Quality), Disasters, Ecological Forecasting, and Water Resources.[1] The Program includes climate-related influences and impacts within each of these themes.

The Health & Air Quality Applications area encourages the use of Earth observations in air quality management and public health, particularly involving environmental health and infectious diseases. The area also addresses the effects of climate change on air quality and public health to support managers and, ultimately, decision-makers of health-related issues.

II. Overview of 2015

[1] The nine USGEO SBAs are Agriculture, Climate, Disasters, Ecological Forecasting, Energy, Health, Oceans, Water Resources, and Weather.

The past year was a productive one for the Health & Air Quality Applications area, with projects concluding or achieving significant milestones. Projects addressed public health issues such as air quality, infectious diseases, vector-borne diseases, environmental health, and harmful algal blooms (HABs). Nine new projects selected for funding through a ROSES 2013 solicitation began work in 2015. Current projects in the portfolio met or exceeded expectations regarding technical performance. In addition, projects received media coverage or substantial praise from stakeholders on the value of the respective applied science.

The Health & Air Quality program continued to support online resources to disseminate important information and data covering health surveillance, the effects of global climate change on public health, and air quality management. The applications area distributed applied research results and led or participated in meetings across the air quality Earth science community, at both the national and international levels.

The following report summarizes a few challenges and many achievements that occurred during 2015. The Health & Air Quality Applications area looks eagerly toward the coming years, including future solicitations, continued support for airborne field campaigns, as well as the support of, and applications planning for, relevant satellite missions.

III. Major Accomplishments

Some of the notable programmatic achievements this past year include:

A project to evaluate and enhance *Suomi National Polar-orbiting Partnership (S-NPP)* products for air quality and public health continued to show progress. This project will improve the application of the Visible Infrared Imager Radiometer Suite (VIIRS) aerosol product for the operational monitoring of fine particulate matter ($PM_{2.5)}$ in EPA's Remote Sensing Information Gateway (RSIG). This project is also incorporating Ozone Mapping Profiler Suite (OMPS)-based estimates of surface UVB irradiance. These results will be provided to the Centers for Disease Control and Prevention's (CDC) Environmental Public Health Tracking Network (EPHTN), where they will be used to provide both health advisories to the public and inputs to skin-cancer research.

Aura satellite data products are being used to provide county-level UV exposure information for the EPHTN to develop environmental indicators and measures as well as conduct epidemiological and linkage studies. The EPHTN end-users will use the data to meet the congressional mandate to track and report environmental hazards and the related health endpoints, including melanoma. Although exposure to UV radiation is well-known to be the main cause of skin cancer, CDC currently does not provide any indicators of UV exposure. Skin cancer, the most common type of cancer in the U.S.,

represents a significant and growing public health burden. The lifetime risk of melanoma in the U.S. has grown dramatically, from 1-in-1500 in the 1930s, to 1-in-58 in 2009.

A project for monitoring and surveillance of cyanobacterial harmful algal blooms (CyanoHABs) in drinking and recreational water supplies alerted city and state officials to a particularly severe HAB in Lake Erie in summer 2015. This HAB was more severe than the one in summer 2014 which led officials in Toledo, Ohio, to shut down the municipal water supply due to potential contamination. This project, in partnership with the National Oceanic and Atmospheric Administration (NOAA), utilized MODIS observations to monitor CyanoHABs in western Lake Erie, Saginaw Bay, and several other lakes and estuaries. This information was assimilated into NOAA HAB bulletins which were subscribed to by multiple state and local offices. Thanks to accurate forecasting and the experience of 2014, end-users were prepared for this HAB and undertook mitigating efforts to ensure no interruption to the public water supply. In addition, the satellite-derived products that were developed for western Lake Erie were analyzed for their use in other regions (e.g., Chesapeake Bay and inland lakes in Ohio and Florida). This project established methods to identify environmental thresholds that indicate the potential for cyanobacterial blooms to form or persist, and these data sets were made available to CDC.

EOS, Earth & Space News, a publication of the American Geophysical Union, published an article entitled, "Agencies Collaborate, Develop a Cyanobacteria Assessment Network," in the November 2015 issue. This article highlights the research that has been conducted by program PI Richard Stumpf of NOAA, and its expansion nationwide through a consortium of NOAA, NASA, EPA, and USGS. Link: https://eos.org/project-updates/agencies-collaborate-develop-a-cyanobacteria-assessment-network

An environmental health project developed a deterministic model for predicting and simulating pollen release and downwind concentration to study dependencies of phenology on meteorology. This model developed a real-time, rapid response pollen release and transport system as a component of the New Mexico Environmental Public Health Tracking System (EPHTS), based on meteorological models and NASA Earth science results, including Moderate Resolution Imaging Spectroradiometer (MODIS) and NPP-VIIRS.

The Program led the development and signing of a new five-year Memorandum of Understanding (MOU) with EPA. This new MOU was signed by Administrator Bolden and Administrator McCarthy in April 2015.

An air quality applications project successfully enhanced the accuracy of air quality models (WRF/MM5/CMAQ) used in defining emission control strategies for state implementation plans (SIPs) by improving the representation of the physical and chemical atmosphere in the models using three distinct pathways: 1) improving location and timing of clouds in the models; 2) improving trace gas (i.e., ozone, nitrogen oxide

(NO_x)) initial conditions in the air quality models; and, 3) utilizing NASA's Lightning NOx-production Model that accounts for lightning-generated nitrogen oxide production in convective clouds. This project was in partnership with the Texas Commission of Environmental Quality (TCEQ).

The NASA Air Quality Applied Sciences Team (AQAST, *http://aqast.org*) focuses on exploiting Earth science data and tools to serve the rapidly evolving needs of U.S. air quality management. Team members conduct individual applied research projects in collaboration with air quality managers, and participate in ad hoc, yearly-competed Tiger Teams for rapid-response applications. AQAST meetings are conducted every six months to review progress and meet with managers from state, local, and regional air quality agencies, as well as industry. AQAST action items are identified at these meetings on the basis of the needs expressed by the air quality agencies.

The 9th semiannual AQAST meeting took place in June 2015 (Saint Louis University) and the 10th meeting will take place in January 2016 at EPA – Research Triangle Park. The meetings last 2.5 days and have become major events in the air quality management and applications communities, typically drawing more than 100 participants. The rising participation of air quality managers has led to dedicating a full day of the meeting to "Air Quality Managers' Sessions" where AQAST members hear from air quality managers about their needs. Discussion panels are a major element of these sessions. All AQAST meeting presentations are posted on the AQAST website.

Other instruments of communication between AQAST members and air quality managers include the AQAST Media Center (aqast-media.org) and the AQAST Newsletter published on a semiannual basis. The AQAST Newsletter has been expanded to feature major success stories of AQAST members working with air quality managers (http://www.aqast-media.org/#!aqast-stories/c1e8l). The AQAST Twitter account has about 2,000 followers. It promotes new research of the team, connects with air quality management agencies, and offers a mechanism to communicate NASA science related to air quality to the public and stakeholders.

Major AQAST highlights during 2015 included:

- AQAST co-organized the Transboundary Ozone Pollution in the Western U.S. conference in collaboration with the San Joaquin Valley Air Pollution Control District. Daniel Jacob served on the steering committee and AQAST played a major role in promoting the conference and selecting speakers. The conference was held on March 31-April 2 at Yosemite, Calif., and featured near-equal participation of air quality scientists and managers. Seven AQAST members participated and gave presentations on different aspects of the problem. By all accounts, the conference was of considerable value to air quality managers in California and other western states.

- AQAST deputy leader Tracey Holloway chaired the 2015 Energy Summit at the University of Wisconsin-Madison in October, featuring a number of AQAST members and collaborators. The theme of the summit was "Air & Energy: The Path Ahead for U.S. States." Experts spanned industry, academia, and regulatory agencies, discussing major topics facing states -- including the new ozone standard, the Clean Power Plan, and the growing importance of satellite data. The Energy Summit Keynote, on the Clean Power Plan, was given by EPA Region 5 Director Susan Hedman.

- AQAST members Russ Dickerson, Bryan Duncan, and Anne Thompson received considerable media attention at their December AGU press conference on global NO_2 trends seen from space. The story was picked up by BBC, CNN, and numerous other news agencies around the world, and the video from their press conference has 100,000 hits. Bryan Duncan also developed a NASA website, "Air Quality from Space," with NO_2 satellite data and imagery curated for easy access by air quality managers.

- AQAST members Meiyun Lin and Arlene Fiore received substantial media attention for their Nature Communications article on how La Niña conditions increase background surface ozone in the western U.S. through increased frequency of stratospheric intrusions.

- AQAST Tiger Teams continue to build extraordinary partnerships between AQAST scientists and air quality managers. The biggest of these teams, focusing on air pollution episodes across the eastern U.S., has engaged more than 20 air quality managers representing 15 state and federal air-quality management agencies. Through monthly phone meetings, all with high levels of participation, the AQAST scientists share recent work, answer questions, and respond to science needs from participating agencies.

- "AQAST: Building a Legacy" video was released in 2015 (https://youtu.be/WicdzZPrIsE). This video contains testimonials filmed at AQAST 9 in St. Louis in June. The video features interviews touting AQAST success with Daniel Jacob (AQAST Leader), Brad Pierce (AQAST Team Member), Arlene Fiore (AQAST Team Member), Rob Kaleel (Executive Director of the Lake Michigan Air Directors Consortium), and Angie Dickens (Air Policy Analyst, Wisconsin Department of Natural Resources).

In December 2015, the Program issued a new solicitation in ROSES 2015 for a "Health and Air Quality Applied Sciences Team (H-AQAST)." This solicitation supports the formation of a team to execute projects on specific applied topics and demonstrations required to advance the health and air quality management communities' sustained use

and application of Earth science observations and models in decision making. This solicitation is a partial follow-on to the AQAST solicitation competed in ROSES 2009. H-AQAST will build on the lessons and successes of AQAST. While many elements of H-AQAST will be similar to AQAST, specific topics will differ. H-AQAST will address topics at the intersection of the health and air quality communities, but will also address issues unique to each community. Proposals are due on March 11, 2016.

IV. Assessment

The most common technical issue in the portfolio in 2015 remained the final transfer of projects to sustainable operations. Many projects have performed admirably in this task, while others still faced hurdles in completing this final step. The most common hurdle appeared to be more related to partner budget issues rather than partner capacity. Overall the portfolio exceeded expectations on technical performance.

The portfolio continued to carry a high burden of uncosted funds in 2015. Associates worked diligently with principal investigators to uncover issues at their particular institutions. Many times this appeared to be an issue of "invoice lag" between NASA and the institutions, with costed funds not showing on NASA accounts until long after invoices had been submitted by grantees. However, significant progress was made. The program saw a 71 percent reduction in FY14 uncosted funds by the end of 2015.

Overall, the portfolio had a good track record for remaining on schedule in 2015, with limited no-cost extensions approved based on new opportunities or partner issues.

In general, the portfolio accomplished significant results and accomplishments in all areas in 2015, with a bright outlook for 2016.

V. Project Portfolio

At the end of 2015, the Health & Air Quality portfolio included 12 projects along with the activities of the 19-member Air Quality Applied Sciences Team. The portfolio met or exceeded expectations on technical performance. By the end of the year, four projects had an Application Readiness Level (ARL) of 1-3; seven projects were ARL 4-6; and one project had achieved an ARL of 7. Year-to-year ARL statistics are not meaningful at this time as the new ROSES 2013 grants were not awarded until February 2015. The appendix of this report includes project highlights for 2015.

VI. Program Management

The Program conducted its 2015 Annual Team Meeting in September in Park City, Utah. Approximately 35 attendees participated. Highlights included a partner address from CDC and two state perspective addresses from the Utah Department of Health and the Utah Division of Air Quality. Additionally, there was a keynote address from Brian Montgomery of JHU/APL. Each of the nine new ROSES 2013 awards presented on their plans for the coming year, ARL estimates, budgets, and any risks/opportunities foreseen. There were also presentations from awards through the *Aura* and *NPP* solicitations. Each of the areas of Capacity Building provided input on their intersections with health and air quality. A Town Hall on Decadal Survey priorities of the community ended the meeting. Topics discussed included: data access/latency/documentation, thermal data needs, alternative platforms (personal sensors, drones, cubesats, etc.), new partnerships (pharmaceutical/healthcare industry, oil/gas industry, etc.), and new paradigms (challenges, prizes, etc.). Presentations from the 2015 review can be found at http://weather.msfc.nasa.gov/conference/phconference_agenda_pc.html.

Associates and Headquarters program management continued to meet regularly through 2015 to coordinate on costing issues, progress on project metrics, conference and workshop presentations, and on project results highlighted through web features or other internal and external venues. These discussions were briefed bi-monthly to Applied Sciences leadership at regularly scheduled program reviews.

Associates for Health & Air Quality continue to be Sue Estes (University of Alabama-Huntsville) and Ali Omar (NASA Langley Research Center). Additionally, the Program added a valuable asset in Shobhana Gupta, a new American Association for the Advancement of Science (AAAS) Fellow.

VII. Community Leadership

The applications area presented and led sessions at meetings of the American Thoracic Society, the Air & Waste Management Association, and the American Meteorological Society (AMS). Sessions at the AMS annual meeting in Phoenix were held as part of the Sixth Conference on Environment and Health, of which NASA is a standing committee member. The conference's theme was, "Fulfilling the Vision of Weather, Water, and Climate Information for Every Need, Time, and Place." The 2015 meeting explored how weather professionals are turning this vision into reality by focusing on the scientific, technical, and professional advances – ongoing and anticipated – required to develop and deliver widespread, customized weather, water, and climate information. NASA co-chaired the conference, and several investigators from the Health & Air Quality Applications area presented papers. Jeff Luvall and Dale Quattrochi of NASA Marshall Space Flight Center (MSFC) received the Landsberg Award from the AMS.

The American Thoracic Society's Annual Meeting was held in May 2015 in Denver. NASA organized and chaired a session entitled "NASA's Satellites and Their Use in

Studying Air Quality as PM 2.5 and Wildfires." This session included presentations from NASA, the University of Wisconsin, the University of Colorado, and Emory University. The session was well attended and had high visibility due to recent wildfires in the western United States.

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The Air and Waste Management Association's Annual (AWMA) Meeting was held June 22-25, 2015, in Raleigh, N.C. NASA was a sponsor of this conference – the largest one focused on air quality in the nation. Every year the conference selects a topic and speaker to present a critical review of an important subject in the air quality community. In 2015, a member of AQAST (Arlene Fiore (Columbia U.)) presented the AWMA Annual Critical Review titled "Air Quality and Climate Connections". The NASA exhibit booth/Hyperwall display showcased NASA satellite observations and modelling animations, and Hyperwall talks by several NASA scientists and partners drew large crowds. NASA speakers presented Health and Air Quality Applications' program information and research during the platform sessions. NASA has agreed to continue its participation at the 2016 Annual Meeting in New Orleans.

The NCAR/CDC Symposium on Climate and Health was held in Boulder, Colo., in July 2015. This symposium focused on vector-borne diseases related to human health. The symposium discussed a wide variety of vector-borne diseases, including dengue fever, Lyme's Disease, and plague, and their relationship to climate variability and change.

The CDC EPHT Grantee Meeting was held in Atlanta in August 2015. This meeting focused on the tracking network's operations with state and local governments. The Program gave a presentation on the EPHT climate change portal developed at MSFC and the types of environmental data that are available for end-users.

The American Society of Tropical Medicine and Hygiene's (ASTMH) annual meeting was held in Philadelphia in October, 2015. NASA's presentation focused on predicting and characterizing outbreaks of infectious and vector-borne diseases through the use of satellite remote sensing and model predictive capabilities.

The Program Manager keynoted the "SHaring Our Research with Everyone: A Research Symposium for Students, Scientists and the Community (SHORE)" in Daytona Beach, Fla., on November 6. The focus of the talk was the intersection of public health and water quality as the symposium was focused on water quality and ecological threats to the Indian River Lagoon of the Florida Atlantic coast.

The American Geophysical Union's Fall Conference was held in San Francisco in December 2015. The meeting offered multiple general sessions, each covering a different and exciting topic applicable across all fields of Earth and space science. The Health and Air Quality Applications Program chaired a session: "The NASA Public Health and Air Quality Applications Program: Integrating Remote Sensing, Spatial Analysis, and Modeling for the Analysis of Environmentally Driven Human Health Risks." A paper was also presented as part of the session entitled, "Satellite Models for

Global Environmental Change in the NASA Health and Air Quality Applications Program." The team organized a poster session and presented talks at the NASA Hyperwall. AQAST investigators also presented in multiple oral and poster sessions. AQAST investigator Anne Thompson (NASA Goddard Space Flight Center) received the Revelle Medal.

The program continued its active participation in the USGCRP Climate Change and Human Health Working Group (CCHHG) in 2015. Through the CCHHG, the program contributed material and authors for the National Climate Assessment and the "Interagency Special Report on the Impacts of Climate Change on Human Health in the United States," which is expected to be published in May 2016.

A NASA web feature, "Air Quality: A Tale of Three Cities," was released in March, featuring AQAST investigator Bryan Duncan (NASA Goddard Space Flight Center). A NOAA web feature, "NOAA and Partners Predict Severe HAB for Lake Erie," was released in July. *The Washington Post* featured the CDC WONDER project in an article entitled, "Mapped: The Sunniest Spots in America," in July. The article described how solar insolation data from NLDAS was assimilated into the CDC WONDER system to map average daily sunlight by month across the conterminous U.S. (CONUS). These maps were facilitated by the ROSES 2008 grant to Dr. Leslie McClure of the Univ. of Alabama-Birmingham. The program also saw media coverage of its activities across multiple sources including The Weather Channel, *USA Today*, Accuweather, and *Nature*.

VIII. International Activities

The program continued its participation in the GEO Health and Environment Community of Practice (CoP). Program contributions are particularly relevant to GEO tasks HE-01-C1: Air-borne Diseases, Air Quality and Aeroallergens, and HE-01-C3: Vector-borne Diseases. Rick Lawford (International Institute for Sustainable Development) presented at the 2015 GEO Workplan Symposium. Key accomplishments noted included: 1) the iimplementation of real-time air quality systems including EPA's AirNow-International (ANI) platform in many regions across the globe, including China and Mexico; 2) the establishment of a basis for a system for early warning of dengue and malaria for decision support to local health authorities in India and Africa; 3) the establishment of a real-time cholera early warning system; and, 4) notable progress toward a global observation system for mercury by harmonizing standard operating procedures for monitoring mercury and its compounds in air, precipitation samples, surface water, soil, sediments, vegetation and biota. Additionally, the Health CoP proposed an initiative to GEO on a global observing system for persistent chemical pollutants. While no meeting of the Health CoP occurred in 2015, the next meeting is tentatively planned for 2016.

The program presented at the 2nd meeting of the World Health Organization (WHO) Global Platform on Air Quality and Health in August in Geneva, Switzerland. The meeting was convened by WHO in collaboration with World Meteorological Organization (WMO) to review progress in the development of capacity for global assessment of population exposure to air pollution. The meeting evaluated implementation of recommendations from the first meeting and defined further relevant work for the WHO and the platform partners.

The program collaborated with the WHO and NASA SERVIR in 2015 to investigate the viability of extending results from previous projects on hemorrhagic fever risk characterization in sub-Saharan Africa to the ongoing Ebola virus outbreak in West Africa.

The Program partnered with Capacity Building when former President Jimmy Carter contacted Administrator Bolden in spring 2015 requesting NASA's help in locating Yanomami villages in the Amazon to support The Carter Center's onchocerciasis ("river blindness") eradication efforts. A DEVELOP summer 2015 project found evidence of more than 160 potential villages in the study region by using a combination of NASA Earth observations and commercial imagery. Results and methods were delivered to The Carter Center in August 2015. The Carter Center will use these tools in its work to eradicate river blindness in the Americas.

By the end of 2015, the emerging Zika virus pandemic in Latin America began to garner attention from the program. The program is investigating how to leverage current mosquito-borne projects on dengue fever and chikungunya virus at NASA MSFC and UC-Davis to address the spread of this disease.

IX. Looking Ahead

During 2016 and beyond, the program will continue to expand its relationship with current and future relevant NASA missions, as well as field and Earth Venture (EV) campaigns. The area also plans to hold the final AQAST results workshop in January at Research Triangle Park, N.C., in cooperation with EPA.

The program looks forward to the competitive selection of a new Health and Air Quality Applied Sciences Team (H-AQAST) in summer 2016, as well as the selection of socio-economic benefit augmentations to ROSES 2013 awards.

Sessions in 2016 are planned for the AMS Annual Meeting, American Thoracic Society, Air & Waste Management Association, the National Water Quality Monitoring Conference, and the American Society for Tropical Medicine and Hygiene.

The launch of the *Global Precipitation Measurement* Core Observatory (GPM) in 2014 inaugurated an unprecedented international satellite constellation to produce frequent global observations of rainfall and snowfall. The mission will provide revolutionary new data that will help answer questions about our planet's life-sustaining water cycle, as well as improve weather forecasting, water resource management, vector-borne disease risk assessment, and habitat modeling. In June 2015, the Applied Sciences Program and the Precipitation Measurements Missions team hosted the second GPM Applications Workshop in College Park, Md. Participants reviewed products available from GPM, gaps in user communities, impediments to utilizing GPM data, issues with TRMM/GPM transition, and challenges/opportunities facing the community over the next decade. Breakouts sessions were organized around the Applied Sciences' focus areas, and those groups identified new users and communities to engage, both long- and short-term barriers to using GPM data, and key challenges that could be addressed by the next Decadal Survey. Additionally, the Applied Remote Sensing Training (ARSET) program provided a hands-on GPM user training workshop at the conclusion of the meeting. A third GPM Applications Workshop is planned for late 2016.

The program will continue to keep abreast of studies and opportunities related to the PACE, ASCENDS, OCO-2, HyspIRI, and GEO-CAPE decadal survey missions. Additionally, the program is active in applications planning for the TEMPO Earth Venture mission, to be launched no earlier than 2018. A TEMPO Applications Workshop is planned for July 2016 in Huntsville, AL.

The program will continue to examine "grand challenges" to the community. For example, accurate ground-level aerosol and constituent measurements from remotely-sensed columnar values represent another grand community challenge. While progress has been made in this area thanks to investments in algorithm development and targeted field campaigns, large discrepancies still remain. Ozone is a critical issue in this regard; aerosols over land areas with high albedo also have large errors. Even developed countries, such as the United States, have relatively sparse ground-level aerosol networks with remotely-sensed observations providing critical data to fill coverage gaps. Developing countries have even fewer ground sensors, and sometimes none at all. Satellite observations for air quality will be increasingly vital in the coming years.

The Health and Air Quality Applications program has established strong relationships with federal, state, local, and international partners to identify unique applications of NASA satellite observations and realize their operational use. These applications provide critical components for integration with various forecasts, models, and decision support systems. This will continue to be the case with the launch of upcoming NASA satellite missions. NASA's participation in health and air quality applications research and related transition to operations activities currently performed with EPA, NOAA, CDC, and others fills a significant niche in national capabilities and is a vital component of both current and future domestic and international programs and plans.

X. Appendix

Active Health & Air Quality Project Highlights from 2015

Project: Enhancing Data-driven Decision Support for Highly Invasive Vectors,

PI: Christopher Barker

Organization: University of California, Davis

- This new project, awarded through the NASA ROSES 2013-HEALTH solicitation, was developed for the creation of distribution and suitability maps for invasive mosquitoes, *Aedes albopictus* and *Aedes aegypti*. These mapping systems will use near-real-time mosquito surveillance data, as well as NASA and non-NASA earth observations. These maps will be used to drive generalizable stochastic models for mosquito dynamics and spread on real landscapes to guide surveillance and control. This mapping system will be used to link models to real-time surveillance data through integration and evaluation in the CalSurv Gateway decision support system. The package models are expected to be adopted in other locations in the U.S. and southern Europe.

Project: Incorporating Space-borne Measurements to Improve Air Quality Decision Support Systems

PI: Arastoo Pour Biazar

Organization: University of Alabama in Huntsville (UAH)

- The uncertainties in air quality simulations due to model cloud errors have been recognized as a major problem in SIPs of state regulatory agencies. This project developed two parallel techniques for minimizing estimates of cloud formation/removal based on satellite observations. The techniques are implemented within the Weather Research and Forecasting (WRF) model which is commonly used in regulatory air quality applications. Both approaches estimate a required vertical velocity and adjust the model flow field through a variational technique to achieve the estimated vertical velocity. The first approach estimates a favorite vertical velocity based on model statistics and the second approach uses an analytical technique for such estimation. Both approaches were tested and demonstrated improvements in model cloud simulations. The project entered its final year in 2015 with an ARL of 7 as a result of the transfer of the project to the Texas

Commission on Environmental Quality (TCEQ). The Photosynthetically Active Radiation (PAR) products PAR have been evaluated, produced and distributed.

Prior to final transfer to TCEQ, the *GOES* and MODIS skin temperature products were evaluated and used in the model, and the effects of satellite-based PAR on biogenic emission estimates were evaluated. The first system was transferred to TCEQ and has been integrated into their operational setting. To make the transition efficient, the system was tested with a data feed and configuration similar to the operational setting at TCEQ. TCEQ is provided complementary funding of $350,000 for the cloud work in order to address specific issues relevant to the SIP process for Texas and has signed a cooperative agreement with UAH to facilitate this relationship. The team worked with the NASA SPoRT Center to revise the data archive and delivery system. The team also addressed long-term sustainability at TCEQ and other agencies by offering workshops to train users and build capacity.

Project: Improve EPA's AirNow Air Quality Index Maps with NASA Satellite Data

PI: Philip G. Dickerson

Organization: U.S. Environmental Protection Agency

- This project combined data from MODIS (AOD), OMI (nitrogen dioxide), and other sources to supplement measurements from ground-based monitors. The project team created the AirNow Satellite Data Processor (ASDP) to make operational use of satellite data products. The project increased the accuracy of P air quality forecasts due to improved information about the spatial distribution of $PM_{2.5}$. The project reduced relative errors in estimating surface $PM_{2.5}$ from satellite data, and eliminated the need for an online calculation of the AOD/ $PM_{2.5}$ ratio. In 2014, the project completed a survey of the socio-economic and financial benefits of adding NASA satellite data to AirNow using face-to-face interviews in three case study locations (Denver, Atlanta, and Kansas City, Mo.) (*http://www.ctg.albany.edu/projects/pubs?proj=airnow&sub=pubs*). The ASDP system has been integrated into EPA AirNow-Tech decision support system and within the production AirNow Information Management System at the AirNow Data Management Center in California. The products are being produced and sustained on the project website and EPA intends to keep the system in operation under AirNow program resources. As a result, there has been a significant improvement in the information available to air quality forecasters, public health managers, and the public. Local public health agencies now have the ability to more accurately warn the public of high $PM_{2.5}$ levels.

  "What I hope can come from [the satellite products] is the ability to look at more data analysis to allow us to anticipate health impacts, particularly as it relates to

emergency room visits, doctor visits, [and] provider visits, related to asthma and upper respiratory illness," said Bert Malone, deputy director of the City of Kansas City, Missouri, Health Department.

The project team has implemented a NRT World Mapping System in the AirNow-Tech Navigator using LANCE MODIS products. The team also linked the NASA Global Imagery Browse Services (GIBS) in the AirNow-Tech Navigator. The GIBS are a set of standard services to deliver global, full-resolution satellite imagery in a highly responsive manner. The socioeconomic benefit analyses of the AirNow-Tech task reached new milestones when interviews with end-users were conducted in Denver, Atlanta, and Kansas City, Missouri.

During the extended phase of the project in 2015, a study was conducted to analyze the socio-economic benefits of AirNow by interviewing air quality managers in Denver, Atlanta, and Kansas City, MO. The study found significant value in the satellite data (http://www.ctg.albany.edu/projects/pubs?proj=airnow&sub=pubs) in eight subthemes ranging from 'filling the gaps in ground sensor networks' to 'supporting science education and workforce development'. The project's direct societal benefits include:

- Increased accuracy of $PM_{2.5}$ air quality forecasts due to improved information about the spatial distribution of $PM_{2.5}$ concentrations.
- Reduced adverse health impacts on sensitive populations resulting from more accurate air pollution warnings and health alerts.
- Increased public viewing and understanding of air quality maps on AirNow because of greatly improved spatial coverage.
- Increased media use of AirNow air quality maps resulting from expanded geographic coverage.
- More comprehensive air quality stories available to the media because of improved graphical and geographical representation of pollutant transport resulting from unusual events.
- Better communication with the public about the spatial distribution of air pollution, especially in sparsely monitored areas, resulting in better public understanding of these issues.
- Improved information that can be used by air quality agencies when evaluating exceptional events (i.e., events for which there are no local controls).
- Enhanced ability of air quality agencies to identify sources of regional haze and correctly apportion accountability.

AirNow also builds the capacity and framework necessary for future NASA Earth Science Data sets as they become mature and available to the air quality

community. The existence of this framework can be used for future satellite measurements, ensuring that the benefits listed above are sustainable.

Project: Inverse Modeling and Attainment Analysis for Improved Decision Support of $PM_{2.5}$ Air Quality Regulations

PI: Daven K. Henze

Organization: University of Colorado

- Long-term exposure to fine particulate matter is associated with adverse health effects such as premature mortality, ischemic heart disease, and congestive heart failure. In 2011, the World Health Organization estimated that urban outdoor air pollution is the cause of approximately 1.3 million premature deaths worldwide per year. Of these, the U.S. EPA estimates that 141,000 cardiopulmonary and lung cancer deaths are due to exposure to $PM_{2.5}$ in North America. Studies have suggested that $PM_{2.5}$ mixtures with a high concentration of BC may have greater effects on mortality than mixtures low in BC. Quantifying the role of emissions from different sectors and different locations in governing the total health impacts is critical towards developing effective control strategies. To answer such questions, an adjoint model can provide sensitivities of excess mortality (through the use of the concentration response functions) with respect to emissions at a highly resolved spatial and sectoral level of specificity. The results of the adjoint models developed under this project provide information regarding the impact of individual sources on multiple nonattainment monitors, inform updates to the National Emissions Inventory (NEI) for the $PM_{2.5}$ precursors (NH3 and NOx), and assist the Regulatory Impact Assessment by improving the specificity of cost-per microgram metrics in terms of spatial resolution and source attributes. By constraining the U.S. ammonia emissions using NASA's Tropospheric Emission Spectrometer and the GEOS-Chem adjoint model, the project has demonstrated a reduction in the uncertainties in the U.S. ammonia emissions and recently documented the results in a refereed journal. Additionally, the project quantified impacts on human health of aviation emissions using the GEOS-Chem model. Significant accomplishments in model development over the last year included the use of remote sensing observations to constrain emissions of short-lived species, and adjoint models for aerosol-gas partitioning.

  In 2015 the Community Multiscale Air Quality (CMAQ) adjoint model was updated to include aerosol and to quantify the role of emissions from different sectors and different locations on premature mortalities attributed to exposure to BC. A majority of mortalities are attributed to exposure to BC occur in highly populated areas. The models show for the first time the fraction of the mortality owing to transport from less populated regions. The results suggest that placing

emissions regulations on the locations with highest emission would not necessarily be the most effective strategy to reduce mortalities attributed to BC exposure. Several areas upwind of highly populated areas have a much higher contribution to mortality than local incidence of mortality itself.

Project: A Multi-Sensor Remote Sensing Approach to Predict Cholera

PI: Antarpreet Jutla

Organization: West Virginia University

- This new project, awarded through the NASA ROSES 2013-HEALTH solicitation, will develop a satellite derived cholera prediction system, linking macro- and micro-environmental processes, for better decision-making strategies to prevent or minimize the impact of an outbreak. This team is identifying and synthesizing the role of acro-environmental processes for epidemic, mixed-mode endemic, and endemic cholera; developing a satellite data driven hydroclimatological risk model from conditions favorable for the three types of cholera; and developing a population based cholera outbreak index. This project will enhance the decision making of several health organizations; provide tools to justify development of appropriate water and sanitation infrastructure in the susceptible regions; and aid in understanding the impacts of climate change on the occurrence of outbreaks. This project hopes to inform the development of suitable long-term climate change adaptation policies regarding cholera.

Project: Evaluate, Enhance, and Apply Aura Products in Public Health Tracking

PI: Yang Liu

Organization: Emory University

- This interdisciplinary team brings together experienced remote sensing experts, environmental exposure modelers, and epidemiologists. By integrating ground observations and atmospheric chemical transport model simulations, the team plans to enhance the existing OMI surface UV (OMUVB) product by better accounting for the impact of absorbing aerosols in the retrieval of surface UVB irradiance and erythemal doses. In addition, OMUVB uncertainties due to SO2 and NO_2 absorption will be analyzed and corrected primarily in polluted urban regions. The conversion from the dose rate estimated at OMI overpass time to that at the local noon time and eventually to the daily-average dose will also account for diurnal change of aerosols. After evaluating the accuracy of the enhanced OMUVB product with ground measurements, the project will spatially match OMUVB exposure doses to 3,100

U.S. counties to study the association with county-level melanoma incidences reported by the National Cancer Institute. Major confounding factors such as indoor tanning use, education, poverty, health insurance, and rural-urban status will also be processed and included in the epidemiological model. The project team will work closely with the CDC Tracking Branch to develop UV exposure indicators and measures as well as detailed documentation for public release on the Tracking Network.

Project: Chemical Data Assimilation and Analog-Based Uncertainty Quantification to Improve Decision-Making in Public Health and Air Quality

PI: Luca Della Monache

Organization: University Corporation for Atmospheric Research

- One of the key tools used by decision makers across the U.S. to protect the public from adverse health effects caused by poor air quality is the NOAA/National Centers for Environmental Prediction (NCEP) operational air quality forecasting system. To enhance this decision-making activity, this project was funded in 2015 to improve the accuracy of NOAA/NCEP short-term predictions of ground-level ozone and particulate matter less than 2.5 μm in diameter ($PM_{2.5}$) and to provide reliable quantification of their uncertainty, by exploiting NASA Earth Science Data with chemical data assimilation and analog-based approaches. The first objective of the project is to improve the initialization of the NOAA/NCEP operational air quality system, which is based on the CMAQ model, through chemical data assimilation of satellite retrieval products with the Community Gridpoint Statistical Interpolation (GSI) system. The project will use GSI to assimilate retrievals of aerosol optical depth from NASA Aqua/Terra MODIS and carbon monoxide from NASA/Terra MOPITT and the EUMETSAT/MetOp Infrared Atmospheric Sounding Interferometer (IASI). Nitrogen dioxide retrievals from the Ozone Monitoring Instrument (OMI) will be used for constraining emissions. Surface observations of $PM_{2.5}$ (and ground level ozone) from the AIRNow network, the Interagency Monitoring of Protected Visual Environments (IMPROVE) stations, and the Clean Air Status and Trends Network (CASTNET) will also be assimilated. The project is expected to improve (i.e., by estimated 20-50 percent) the CMAQ deterministic predictions and reliably quantify their uncertainty with analog-based post-processing methods applied to the CMAQ deterministic predictions, and extrapolate deterministic and probabilistic point-based predictions to a two-dimensional grid over the U.S. with a Barnes-type iterative objective analysis scheme.

  In 2015, the analog-based post-processing methods and the GSI/CMAQ system for satellite-based chemical data assimilation were tested and evaluated in a pre-operational environment by NOAA/NCEP for the correction of the prediction of $PM_{2.5}$.

In subsequent years, the project will test the prediction of ozone and develop CMAQ deterministic predictions.

Project: An Early Warning System for Vector-borne Disease Risk in the Amazon

PI: William Pan

Organization: Duke University

- This new project, awarded through the NASA ROSES 2013-HEALTH solicitation, is a follow-on grant after successful completion of a Feasibility Study funded through the NASA Applied Sciences Health and Air Quality Program (2011-2013). Members of the proposal team developed a pilot malaria Early Warning System (EWS) for the northern Peruvian Amazon. Results of this study showed that meaningful malaria risk prediction can be achieved using statistical methods informed by an advanced NASA Land Data Assimilation System (LDAS), satellite-derived land cover, and human population and malaria surveillance data. Building on this study, this project will: 1) operationalize the malaria EWS to a larger geographic area with more fine-scale estimates of risk; 2) expand and evaluate system performance of cross-border risk estimates and add additional vector-borne disease endpoints, focusing initially on leishmania; and, 3) evaluate integrated Agent Based Model estimates into predictions. Operational status will be achieved by leveraging existing partnerships with the U.S. Naval Medical Research Unit No. 6 in Peru, and the Ministries of Health of Peru and Ecuador.

Project: Downwind of the Flames: Assessing and predicting wildfire smoke related morbidity using satellites, in-situ measurements and models

PI: Jeffery Pierce

Organization: Colorado State University, Fort Collins, Colo.

- Exposure to particulate matter (PM) in wildfire smoke plumes represents a growing and uncertain threat to public health in the western United States. The area burned by wildfires in this region has increased in recent decades and is expected to increase dramatically over the next century. Wildfires pose a challenge to air quality managers and public health officials. This project was funded in 2015 to estimate the respiratory and cardiovascular health risks for specific demographic populations exposed to wildfire PM and evaluate and develop forecast tools that predict wildfire PM concentrations, population exposure and the potential increased morbidity from exposure to wildfire smoke.

In 2015 the project began with a set of retrospective studies using an array of NASA earth observations (MODIS, MISR, CALIPSO), surface in-situ monitors and high-resolution modeling (3-km WRF-Chem) to estimate past PM exposures during major wildfire events and compile health-care records in the affected and nearby regions to estimate the health risks associated with exposure. In subsequent years, the project will develop forecasting tools for use in decision making regarding wildfire PM using the WRF-Chem model and the BlueSky model framework. These tools will require knowledge of current fires from NASA satellite observations, and will be tested using retrospective case studies using satellite and in-situ observations. Partners span city, state, and federal regions, with anticipated benefits extending to other decision-making across these scales.

Project: Aura Chemical Reanalysis in support Air Quality Applications

PI: R. Bradley Pierce

Organization: NOAA/NESDIS/STAR

- This project was funded by the AURA Science Team to utilize the Real-time Air Quality Modeling System (RAQMS) in conjunction with the Operational Gridpoint Statistical Interpolation (GSI) 3-dimensional variational data assimilation (DA) system to conduct a multi-year global chemical and aerosol reanalysis using NASA *Aura* and A-Train measurements.

  In 2015, the development of the RAQMS/GSI interfaces and updated emission inventories and assimilation of GSI based OMI total column ozone and MLS stratospheric ozone profile assimilation was completed. The resulting ozone analyses has been validated using in situ airborne measurements from the NSF HIPPO III and ozonesonde measurements from the NOAA CalNex field campaigns and are in good agreement. Through the NASA Air Quality Applied Science Team, the project successfully demonstrated the use of RAQMS chemical and aerosol analyses for use as Lateral Boundary Conditions for a regional air quality reanalysis being conducted by NOAA Air Resources Laboratory ARL using a developmental version of the NOAA Operational North American Model (NAM) Community Multi-scale Air Quality Model (CMAQ).

Project: Improved Forecasts of Respiratory Illness Hazard from Gulf of Mexico Red Tide

PI: Richard Stumpf

Organization: NOAA Ocean Service

- This new project was awarded through the NASA ROSES 2013-HEALTH solicitation. NOAA has conducted an operational forecast of algal blooms in Florida for ten years, and four years in Texas. This capability was developed by the PI's office and transferred to NOAA's Center for Operational Oceanographic Products and Services. The associated public conditions report provides an assessment of potential respiratory impact at county levels. The result has been successful in helping state monitoring, but much less so in supporting the broader community. The problem is that this forecast is issued twice per week and covers full county regions, and current capabilities do not support higher forecast resolution. Because the blooms are patchy, the accuracy at individual beaches is extremely low. Mote Marine Lab has implemented a "Beach Conditions Reporting System" (BCRS) that provides immediate information on respiratory irritation at the beach, but does not provide forecasts. Improvements in the integration of field observations, satellite data, and meteorological models will provide the needed higher resolution of the risk of respiratory impact. The goal of this project is to forecast the resolution and frequency of risk to "every beach, every day," rather than every county, twice a week. The methods should be applicable across the Gulf of Mexico. Currently, monitoring uses individual satellite sensors independently. This project will combine the standard products from multiple sensors and will improve the initial conditions going into the forecasts (e.g. removing clouds, loss of data, glint, etc.) and increase the temporal resolution, combining same day *Terra*, *Aqua*, and VIIRS (and ultimately *Sentinel-3*). The BCRS will be significantly enhanced with establishment of a smartphone based capability to allow trained volunteers to rapidly identify the presence of dense *K. brevis* blooms. Effective deployment of this network will be based on locations identified from the integration of new satellite products and previous reports. The result of the combination will be a finer spatial scale than currently available with the weekly water sampling and satellite images. The second part is forecasting the presence of aerosols onshore. The integration of the forecasts with improved daily detection would lead to simple and routine rapid forecasts that would be distributed through NOAA's operational HAB forecast system, the BCRS, the National Weather Service Beach Hazards Statement, as well as county and state public health departments.

Project: Using Remote Sensing and Environmental Data to Quantify Social Vulnerabilities to Heat Stress and Strengthen Environmental Public Health Tracking and Heat Mitigation Effort

PI: Thomas Talbot/Tabassum Insaf

Organization: New York State Department of Health

- This new project, awarded through the NASA ROSES 2013-HEALTH solicitation, will

integrate remote sensing data into CDC Environmental Public Health Tracking (EPHT) and capacity building efforts for climate change resilience at both the state and local health department levels. This project will use NASA Earth observations to characterize risk related to excessive heat in two populous Eastern U.S. states (New York and Florida). A fine-scaled daily heat metrics will be developed using meteorological re-analysis and remote sensing data for the years 2005-2013. Heat metrics will consist of daily maximum and minimum air temperatures, daily maximum heat index, and a newly defined measure called Net Daily Heat Stress (NDHS). The NDHS is an integrated measure of heat stress (and relief) over periods of a day or longer. Data for these metrics will then be incorporated into and made accessible to Local Health Departments through the state EPHT portals. Air temperature metrics derived from meteorological re-analysis and health data (hospital admissions and emergency department visits) are being developed exposure-response functions of heat stress, respiratory, cardiovascular and renal outcomes as functions of excessive heat levels (as defined by four daily heat metrics) and socio-demographic variables at the census tract level. This analysis will allow for development of social vulnerability maps at the census tract level and integrate this information into decision support systems currently used in New York and Florida for community health assessment.

Project: Evaluate and Enhance *Suomi-NPP* Products for Air Quality and Public Health Applications

PI: Jun Wang

Organization: University of Nebraska – Lincoln

- This project is designed to evaluate and enrich the utility of *Suomi National Polar-orbiting Partnership* (*S-NPP*) data for applied science research. This project will evaluate improvements in the application of the VIIRS aerosol product for operational monitoring of $PM_{2.5}$ air quality in the Remote Sensing Information Gateway (RSIG) at EPA. This information will also be provided to the CDC Environmental Public Health Tracking Network.

Project: An Early Warning System for Human West Nile Virus (WNV) Disease

PI: Michael Wimberly

Organization: South Dakota State University

- This new project, awarded through the NASA ROSES 2013-HEALTH solicitation, will improve WNV forecasting and risk mapping tools to advance the effectiveness of

mosquito control by helping to target limited resources more efficiently. This project is developing an improved WNV risk map highlighting infections across the state of South Dakota. The project will produce weekly predictive maps of WNV risk during the main transmission season. To improve predictions the team will incorporate streams of environmental data from current NASA products (NLDAS) and missions (*SMAP*). These methods to improve predictions by integrating environmental monitoring data with entomological surveillance data may be used by other states/areas where outbreaks occur.

AQAST Project Highlights from 2015

Project: Improving Air Quality Analysis through a Closer Integration of Observations and Models

PI: Gregory R. Carmichael

Organization: University of Iowa

- Utilizing data from TES, OMI, SEAC4RS, and other sources, this project seeks to improve the capability of modeling fine particle concentrations during wintertime in the Midwest, Northeast, Mountain West, and California's Central Valley, to establish an operational urban/regional air pollution forecasting system. The goal is to provide decision support to local, state, and regional air quality managers.

In 2015 the project developed and applied a state-of-the-art data assimilation system to constrain emissions. We used airborne, ground-based, and satellite observations to constrain hourly smoke emissions from the Rim Fire in 2010. Emissions constrained with multiplatform data show notable nocturnal enhancements (sometimes over a factor of 20), correlate better with daily burned area data, and are a factor of 2–4 higher than a priori estimates, highlighting the need for improved characterization of diurnal profiles and day-to-day variability when modeling extreme fires. Predictions driven by emissions constrained with multiplatform data present significant variations in downwind air quality and in aerosol feedback on meteorology, emphasizing the need for improved emissions estimates during exceptional events.

We also applied the data assimilation methods to improve the modeled total and background O_3, via re-partitioning and re-distributing the contributions from non-local and local anthropogenic/wildfires sources in a multi-scale satellite data assimilation system containing global and regional models. Using the TES-constrained boundary conditions from our global model assimilation, we then assimilated tropospheric

nitrogen dioxide (NO_2) columns from Aura-Ozone Monitoring Instrument in the regional model to indicate U.S. nitrogen oxides (NOx= NO_2+NO) emissions at 12×12 km2 grid scale. Improved model skills are indicated from cross validation against independent ARCTAS measurements. Leveraging Aura observations, we show anomalously high wildfire NOx emissions in this summer in Northern California and the Central Valley while lower anthropogenic emissions in multiple urban areas than those representing the year of 2005. We found strong spatial variability of the daily maximum 8-h average background O_3 and its contribution to the modeled total O_3, with the mean value of ~48 ppbv (~77 percent).

Project: Inputs influencing ozone and particulate matter concentrations and sensitivities

PI: Daniel Cohan

Organization: Rice University

- This project is simulating ozone and particulate matter and their sensitivities to emissions perturbations, and exploring how these changes with satellite-based inputs and alternate inputs for natural conditions. We have implemented an advanced soil NO emissions scheme and are comparing its predictions of NO_2 with ground-based monitors and OMI satellite-based column retrievals. We are also exploring how *GOES* satellite observations of clouds influence biogenic emissions and photolysis rates, and thereby influence pollutant concentrations and sensitivities.

  In 2015, the project developed a standalone soil NO emission module using the advanced Berkeley Dalhousie Soil NOx Parameterization scheme to estimate to spatial and temporal variations of NO emission flux over the CONUS under different soil biome type, fertilizer application rates, and nitrogen depositions from the atmosphere. This standalone emission module is flexible with the choices of meteorological inputs and is computational efficient. Therefore, it is suitable for long term trend analyses and sensitive studies (e.g. different soil NO emission factors from literature report) to quantify model uncertainty. We also generated a fine scale (12kmX12km) soil biome map over CONUS using the latest land use/land cover database from NLCD and climate zone definitions. We also tested the option to use the soil fertilizer map from EPA's FEST-C EPIC outputs instead of multiyear average product to dynamically represent the variation of fertilizer fields on a day-to-day basis under different farming scenarios.

  With the help of co-PI Arastoo Pour-Biazar (U. Alabama-Hunstville), a new set of high resolution (4kmX4km) satellite based Photosynthetically Active Radiation (PAR) retrievals from the *GOES* visible imagers, which is the key parameter to quantify the biogenic emissions, has been produced and extensively evaluated against available ground pyranometer observations to better represented the radiation fields input for

emission and air quality model due to the impact of cloud. This new set of satellite PAR data were implemented in the WRF-MEGAN-CMAQ simulation platform during the September 2013 Houston Discover-AQ campaign period to quantify its sensitive to biogenic emission estimates and ozone formation. This new set of PAR retrieval products received wide interest from other members in AQAST team and we are now collaborating with our colleague in the Lake Michigan Air Directors Consortium (LADCO) to test the sensitivity of Biogenic Volatile Organic Compounds (BVOC) emission to ozone formation in the Northeastern U.S.

Two manuscripts entitled, "Further steps for improving soil NOx estimates in Community Multi-scale Air Quality model (CMAQ)," and "Incorporating *GOES* satellite photosynthetically active radiation (PAR) retrievals to improve biogenic emission estimates over Southern United States and Texas" has been drafted by Rice graduate student and Postdoc and is being circulated among the co-authors for edits and comments before submittal. The similar contents were presented in several professional conference events such as CMAS, A&WMA, and AMS in 2015.

The team is continuing to achieve the new satellite PAR data over different years and building a web interface for the interested research groups to use those data. We are also recoding the photolysis process module on the basis of CMAQv5.0.2 to adding the functionality in CMAQ model to using satellite based photolysis rate. We are also working with co-PI Loretta Mickley (Harvard) to updating the daily wildfire emission inventory using the national Fire and Aviation Management Web system (FAMWEB) and compare the FAMWEB inventory with EPA's SMARTFIRE2 inventory.

Project: Demonstrate Utility of Aura/OMI Nitrogen Dioxide (NO_2) Data for AQ Applications

PI: Bryan Duncan

Organization: NASA

- This project assesses the utility of *Aura*/OMI nitrogen dioxide (NO_2) tropospheric column data for various air quality applications, including showing the good correspondence of trends and variations estimated from the data with EPA AQS surface NO_2 data and NO_x emissions data reported to the Continuous Emission Monitoring System (CEMS).

  The project team published an article, "U.S. NO_2 trends (2005-2013): EPA Air Quality System (AQS) data versus improved observations from the Ozone Monitoring Instrument (OMI)" (*Atmospheric Environment)*, which provides important details on NO_2 trends and how to interpret the trends. The team developed a NASA "Air Quality" website (https://airquality.gsfc.nasa.gov) that contains OMI NO_2 data

and ready-made plots for individual U.S. cities for U.S. AQ managers to download. Upon the request of several AQ managers, the team prepared analyses of OMI data for their specific applications.

Project: Understanding Colorado Front Range Summertime Ozone, Long-range Pollution Transport and Stratospheric Intrusion Events

PI: David Edwards

Organization: National Center for Atmospheric Research

- NCAR/ACD has taken a large step towards better understanding the drivers behind high summertime ozone in the Colorado Front Range by spearheading a major field campaign in the summer of 2014 – the Front Range Air Pollution and Photochemistry Éxperiment (FRAPPÉ). FRAPPÉ - has been conducted successfully and took place together with the 4th deployment of the NASA DISCOVER-AQ from 15 July – 18 August 2014 (http://www2.acd.ucar.edu/frappe). FRAPPÉ addresses the following main science question: What are the factors controlling surface ozone in the Front Range and are current emission controls sufficient to reduce ozone levels below the NAAQS?

  The campaign yielded the most comprehensive dataset to study and characterize local AQ at a level of detail not possible previously and has been (and is) a showcase for the tight collaborations between the research community and air quality agencies (Colorado Department of Public Health and Environment, the Regional Air Quality Council, EPA Region 8, the Western Regional Air Partnership and the National Park Service).

  The collected data set has been thoroughly evaluated for quality and accuracy and was released to the public in April of 2015. The data set consists of more than a million individual data points covering hundreds of chemical tracers and their oxidation products in the atmosphere, which are crucial for understanding ozone pollution. Analysis is ongoing and conducted collaboratively between the university communities, national agencies such as the NPS, scientists from NCAR, NOAA, and NASA, as well as regulatory agencies including the Colorado Department of Public Health and Environment and EPA. Ultimately the analysis will lead to the development of emission control strategies to reduce summertime ozone pollution in the Front Range and visibility and nitrogen deposition problems in Rocky Mountain National Park.

  From 4-8 May, 2015 ACOM held a community workshop at NCAR for all groups involved in last summer's campaign to present and discuss first results. This meeting was attended by over 200 people. At the upcoming Fall AGU there will be 40+ presentations on FRAPPÉ with most of them presented in a session convened by

AQAST member Pfister on “Air Quality Research: From Emissions to Impact”. In addition to scientific representation E&O has been and continues to be a strong component with recent articles in local news media and projects with a local middle school.

Project: Air quality and climate connections

PI: Arlene Fiore; co-I Meiyun Lin (Princeton University and NOAA GFDL)

Organization: Columbia University/Lamont-Doherty Earth Observatory

- The PI led an invited critical review paper for the Journal of Air and Waste Management that synthesizes findings from studies using long-term datasets from models, space-based and in situ measurements to identify linkages between air quality and climate variability. The manuscript includes a discussion of the impacts of air pollutants on the climate system, including the role of short-lived climate pollutants relative to carbon dioxide, as well as near-surface ozone and particulate matter projections for U.S. regions from the current generation of chemistry-climate models. A summary article for Environmental Manager accompanied the full review paper in June 2015, and the PI gave a plenary presentation at the annual Air & Waste Management that included presentations from four discussants, as summarized in an October 2015 article in the Journal of Air and Waste Management.

  Co-I Lin led a manuscript published in Nature Communications that shows more frequent late spring deep stratospheric intrusions over the Western U.S.A. when the polar jet stream meanders towards the southwestern United States, as occurs following strong La Niña conditions. El Niño and La Niña are the most influential climate patterns used for seasonal forecasts. Recognizing the link between La Niña and late spring stratospheric intrusion frequency over the western U.S. thus offers an opportunity to forecast ozone several months in advance to aid western U.S. air quality managers who may wish to deploy observational platforms to identify exceptional events or to educate the public to minimize adverse health effects from a high-ozone season.

  The team is continuing to use space-based and in situ observations alongside multi-year GEOS-Chem and AM3 simulations for source attribution during specific pollution episodes of interest to air agencies. In the past year, team members have participated in air management workshops, phone conferences and discussions, and have provided scientific results and boundary conditions for regional models as requested by air managers. The PI also co-leads (with Dr. Tracey Holloway) a Tiger Team that is providing information on source attribution during eastern U.S. pollution

episodes and involves approximately monthly calls with more than a dozen air agencies and the AQAST Tiger Team members.

Project: Using OMI Data to Estimate Point Source Emissions and Atmospheric Lifetimes of NO_x and SO_2 / Ozone Garden Project and Coordination of Outreach Activities for AQAST

PI: Jack Fishman; co-I Benjamin de Foy

Organization: Saint Louis University

- This project uses satellite measurements to create high-resolution maps of NO_x and SO_2 around point sources. By better estimating chemical lifetimes and emission inventories, local air quality issues can be better understood. The intended end-users include, among others, developers of emissions inventories at regional agencies. Another aspect of the project is the development of education/public outreach materials for AQAST.

  We have developed a multiple linear regression model for the OMI NO_2 retrievals at the original pixel resolution, using neither temporal nor spatial averaging. This model was able to identify decreased NO_2 columns above metropolitan areas in North America during the recession. The results show that the NO_2 columns were impacted by a combination of long-term trends and recession impacts, and that these differed from city to city. The model also estimates the strength of the weekend effect, which is strong throughout North America but also has significant differences between cities. The manuscript is under review at Atmospheric Environment.

  A paper was published on estimating emissions and NO_2 lifetimes in power plant plumes in the USA. By using data from the CEMS, the study identifies the conditions necessary to make accurate estimates of emissions using OMI NO_2 retrievals. The study further found that lifetime estimates are representative of mixing lifetimes rather than chemical lifetimes (de Foy, B., Lu, Z., Streets, D.G., Lamsal, L.N. and Duncan, B.N., 2015. Estimates of power plant NOx emissions and lifetimes from OMI NO_2 satellite retrievals. *Atmospheric Environment*, *116*, pp.1-11).

  A manuscript entitled, “The Influence of Wildfires and Stratospheric-Tropospheric Exchange of Ozone during SEACIONS Mission over St. Louis,” has been drafted by SLU graduate student Joseph Wilkins and is being circulated among the co-authors (including four AQAST members) for edits and comments before submittal. These results were presented at the poster session during AQAST9.

The St. Louis Ozone Garden remained vibrant and expanded to 11 sites nationally in 2015, with groundwork taking place at two additional sites in the St. Louis area, bringing the total to five local gardens in 2016. The project will continue beyond 2016 with an award from EPA's Environmental Education Program, which will provide funding to build ozone chambers inside of a soon-to-be-completed classroom/greenhouse at the Missouri Botanical Garden (MBG). In essence, we are moving the ozone garden indoors so that students and the lay public can witness the damage of ozone pollution to plants throughout the year. Through field trips, the MBG brings 40,000 students to their facility each year and they will be taught about air quality, global climate change, and the impact of pollution on the biosphere through a series of lessons that will be developed for this project.

Saint Louis University hosted AQAST9, 2-4 June, 2015.

Project: Using Remote Sensing and Adjoint Modeling for Integration of Climate Impacts into Design of Ozone and Aerosol Control Strategies

PI: Daven Henze

Organization: University of Colorado at Boulder

- This project uses combinations of remote sensing data and regional-to-global adjoint sensitivity analysis with the GEOS-Chem chemical transport model to quantify the contribution of emissions to ozone and particulate health, ecosystem and climate impacts. End-users include the U.S. Department of State, EPA, USFS, and United Nations.

  In 2015, following up on previous studies of the source contributions to vegetative ozone exposure, GEOS-Chem adjoint modeling was applied to estimate the contribution from foreign nations and individual states to nation-wide damages to aspen and ponderosa pine trees, as well as to wheat and soy. The team also continued to support ozone gardens at CU Boulder campus and NCAR. We developed emissions response coefficients for climate, ecosystem and human health impacts of aerosol, aerosol and ozone precursor emissions for countries in the western hemisphere. Aerosol exposure is calculated using MODIS-derived $PM_{2.5}$ surfaces; TES O_3 IRKs are used to estimate O_3 radiative forcing. These response coefficients are being used by the U.N. Climate and Clean Air Coalition for their Latin American Assessment. Lastly, as part of the Reactive Nitrogen Deposition Tiger Team, GEOS-Chem and CMAQ sensitivity modeling studies have been performed to estimate the contribution of different sources of NH3 and NOx to deposition of reactive nitrogen above critical loads in US Class I areas.

Project: Increasing the Utility of Satellite Data for Air Quality Management

PI: Tracey Holloway

Organization: University of Wisconsin--Madison

- The project uses satellite data, ground-based measurements, and regional air quality models to evaluate air quality from urban to national scales, and to work with stakeholders to promote the use of NASA satellite data products.
  2015 saw the publication of two research publications: ozone production efficiency using satellite data (Jin and Holloway, *JGR* 2015), and sensitivity of atmospheric NO_2 to meteorology (Harkey et al., *JGR* 2015). Holloway authored an invited article for the *Urbanization and Global Environmental Change Viewpoints* Blog, entitled "What's Next for Air Quality in the United States?" (https://ugec.org/tag/tracey-holloway/). All three articles highlight the value of satellite data to air quality management in the U.S. and globally. We have also greatly strengthened our stakeholder engagement with LADCO and we have worked closely with LADCO scientists to evaluate ozone production efficiency using OMI NO_2 and HCHO products (Harkey et al., in prep).

  Dr. Holloway has presented to a range of stakeholder audiences on the value of satellite data for decision-making, including the Western States Meeting hosted by EPA (May, 2015), the American Thoracic Society Meeting (May, 2015), the Adler Planetarium public career showcase (July, 2015) and as the keynote speaker in the Wisconsin DNR state-wide meeting (October, 2015). Holloway's work with stakeholder engagement was recognized by the AAAS with her invited participation as a Leshner Leadership Fellow, through which she will continue promoting the utilization of satellite data by air quality agencies through 2016 and early 2017

  Holloway chaired a national conference at the University of Wisconsin on "Air and Energy: the Path Ahead for U.S. States," featuring a number of AQAST investigators and air quality management partners. NASA AQAST funding supported the video archiving of all talks. (https://energy.wisc.edu/events/2015-energy-summit/speakers-and-sessions). Holloway co-leads a Tiger Team on air pollution episodes across the Eastern U.S. (with Dr. Fiore), which has produced an engaged community of AQAST members and air quality managers from 15 different states and agencies meeting monthly. Holloway also maintains the @NASA_AQAST Twitter account (near 2300 followers as of 12/7/15) and the www.aqast-media.org website, promoting and tracking press coverage of AQAST activities.

Project: Aerosol Data Products for Assimilation into Air Quality Models

PI: Edward J. Hyer

Organization: Naval Research Laboratory

- This project integrates satellite observations of fires and aerosols with atmospheric prediction models to enhance short-term prediction of fire activity and aerosol loading to support applications needing forecasts of air quality.

  The NRL group developed a simple tool for air quality managers and researchers interested in the problem of long-range transport of Saharan dust to the Caribbean and eastern U.S. This portal (http://www.nrlmry.navy.mil/aerosol/hourly_pm_airnowtech/AirNowTech_GulfCoast.html) allows users to quickly compare short-term forecasts and archived analysis from the Navy Aerosol Analysis and Prediction System (NAAPS) to surface PM observations from EPA AirNow network. In addition to useful information for forecasting short-term impacts of these large aerosol events, this portal demonstrates very clearly the impact of NASA data assimilated into the NAAPS model. By comparing the forecasted impacts at 24 and 48 hours ahead with the model analysis, it is clear that assimilation of NASA satellite data has a strong positive impact on the NAAPS model.

  An NRL research group led by Dr. Hyer and Dr. David Peterson made important advances in understanding the meteorology driving pyroconvection and improving methods for automated detection of pyroconvection and elevated smoke. This work will be presented at the upcoming American Geophysical Union and American Meteorological Society meetings.

  Dr. Hyer also supported the Tiger Team effort led by Pius Lee (NOAA) and Greg Carmichael (U. Iowa), supplying software for MODIS AOD processing and assisting NOAA ARL with testing this software and integrating MODIS AOD data processing into their reanalysis methodology.

Project: AQAST Membership and Leadership

PI: Daniel Jacob

Organization: Harvard University

- The project addresses emerging air quality management issues by using a range of Earth Science data and tools. A major focus is the application of the GEOS-Chem global model with nested resolution over North America. Other applications involve the GISS global climate model for study of chemistry-climate interactions. Interpretation of satellite and aircraft data for US air quality is a top priority.

A major accomplishment for 2015 was the use of NASA SEAC4RS aircraft data, together with concurrent satellite data, to better understand the factors controlling Southeastern U.S. air quality. We showed that the general model overestimates of surface ozone in the region are due in part to an overestimate of NOx emission in EPA National Emission Inventory, and in part to lower-than-expected boundary layer mixing. We found the sulfate PM in the Southeast U.S. has remained acidic despite decreasing SO2 emissions and an excess of ammonia, and suggested that organic PM mixed with sulfate causes departure from thermodynamic equilibrium. The PM acidity promotes in turn the formation of isoprene secondary organic aerosol (SOA). We found that reducing SO2 emissions has a factor 2 co-benefit on PM through associated reduction of isoprene SOA.

Our 2015 work on the interactions of air quality and climate change focused on developing a statistical model using extreme value theory to estimate 2000-2050 changes in ozone episodes at sites across the United States. Using a Point Process (PP) model, we quantified relationships between daily maximum temperature (Tmax) and maximum daily 8-hour (MDA8) ozone in May-September over 2003-2012. An unexpected ~20 percent sites exhibit "ozone suppression" at high temperatures, marked by a significant decrease in the positive ozone-Tmax slope. The PP model can fail to capture ozone-Tmax relationships at these sites, and so we refit the ozone-Tmax slope using logistic regression and a Generalized Pareto Distribution model. We applied the resulting hybrid-EVT model to projections of Tmax from an ensemble of downscaled climate models. We find an average increase of 2.3 days a^{-1} in U.S. ozone episodes (> 75 ppbv) by the 2050s, with a change of +3-9 days a^{-1} at many sites across the Northeast, Midwest, and Southwest.

Project: AQAST Membership

PI: Pius Lee

Organization: NOAA

- This Tiger Team Project assimilates quality assured observations into current state-of-science chemical transport models (CTM) to address an increasingly pressing need of knowing the best retrospective estimates of the long-term chemical composition and evolving trends of the troposphere.

  In 2015, the project team leveraged the momentum of having produced a sample month-long analysis chemical field for a State Implementation Modeling application and continued to improve and test the reanalysis system. One achievement was the configuration of the CTM to include lightning-induced Nitrogen Oxide emissions. Additional tests on the impact of the expansion of the observational data assimilated

and the assimilation frequency of observations were performed. These test quantified that the added data and frequency improved performance and provide definitive guidance on the cost-effectiveness of such investment of expansions (work culminated in Tang et al. *JAWMA,* 2015). Work was done on the transitioning of the analysis modeling system to operations through the adoption of the NOAA/NCEP standardized GSI variational data assimilation methodology. This transition is underway and two tasks are ongoing to assure the satisfaction of the transition: Regression tests associate with the GSI methodology; and generation of error and observation error covariances. The CTM was also upgraded from the U.S. EPA Community Multi-scale Air Quality Model (CMAQ) version 4.7.1 to version 5.0.2. This version upgrade included considerable improvement in dust storm simulations (work culminated in Huang et al., *ACP*, 2015). The CTM upgrade was communicated with the emission-perturbation study task-force of the project team and a dynamic emission management experiment is being performed for the Southeastern U.S.

Project: Improving Satellite Aerosol Remote Sensing Data for Air Pollution Health Research in the Southeastern US

PI: Yang Liu

Organization: Emory University

- This year the project completed: 1) the performance evaluation of NOAA Hazard Mapping System (HMS) active fire products; 2) a study to link WRF-Chem simulated $PM_{2.5}$ exposure estimates with acute respiratory health effects during the 2012 fire season in Colorado; and, 3) an evaluation of VIIRS, GOCI, and MODIS C6 AOD retrievals in East Asia.

  The HMS automatically detects fires using data from multiple satellite sensors in order to maximize its fire detection rate. However, to date, the detection rate of the HMS fire product for small fires has not been well studied, especially with ground data. The project team utilized fire information compiled from ground observations and permit information in Georgia to provide ground truth validation of the HMS active fire product. The results show that the detection rates of the hybrid HMS increase substantially by integrating multiple satellite instruments. The detection rate increases dramatically from 3 percent to 80 percent with the increase of the fire size from less than 0.02 km^2 to larger than 2 km^2. This work is currently in revision for *JGR-Atmosphere.*

  In 2012, Colorado experienced one of its worst wildfire seasons of the past decade. The goal of this study is to explore the relationship of local $PM_{2.5}$ levels with

emergency department visits and acute hospitalizations for various respiratory and cardiovascular outcomes during the Colorado wildfires of 2012 and to determine whether increased air pollution from wildfire smoke was a contributing factor. Case-weighted conditional logistic regression was used to assess the relationship between both continuous and categorical $PM_{2.5}$ and emergency department visits from June 5th to July 6th 2012. For respiratory outcomes, we observed positive, statistically significant relationships between continuous $PM_{2.5}$ and asthma, wheezing, and COPD. These results, combined with previous toxicological and epidemiological studies, provide evidence for the need for further investigate the potential for adverse health effects with exposure to wildfire air pollutants. This work is currently under review for *Journal of Exposure Science and Environmental Epidemiology*.

Satellite AOD at high resolution has become a powerful tool to characterize aerosol patterns in space and time. Using ground AOD observations from the AERONET and the DRAGON-Asia Campaign, as well as from handheld sunphotometers, we evaluated emerging aerosol products from VIIRS, GOCI, and Collection 6 Terra and Aqua MODIS in East Asia in 2012 and 2013. Comparing against AERONET AOD over the the Japan-South Korea region, 64 percent of EDR, 37 percent of IP, 61 percent of GOCI, 39 percent of Terra MODIS and 56 percent of Aqua MODIS C6 3 km AOD fell within the EE. In general, satellite aerosol products performed better in tracking the day-to-day variability than tracking the spatial variability at high resolutions. The VIIRS EDR and GOCI products provided the most accurate AOD retrievals, while VIIRS IP and MODIS C6 3 km products had positive biases. This work is currently in revision for *Atmospheric Chemistry and Physics*.

Project: Air Quality Applied Science Team (AQAST) Membership – Physical Atmosphere

PI: Richard McNider, co-PI – Arastoo pour Biazar

Organization: University of Alabama in Huntsville

Description: Improve the representation of the physical atmosphere in SIP models and air quality forecasting models.

Highlights from 2015:

- In collaboration with Texas Commission on Environmental carried out case study analysis for Discovery AQ September 2013 using satellite skin temperatures to nudge moisture in the Pleim-Xiu scheme rather than 2-m National Weather Service observations. The use of satellite data reduced the RMSE by nearly a degree over the whole domain.
- Provided cloud albedo data to EPA RTP for model evaluation.

- Provided satellite cloud transmittance and cloud top information for use in photolysis calculation for the Reanalysis Tiger Team.
- Continued collaboration with Texas Commission on Environmental Quality on improving biogenic emissions using satellite PAR.
- Worked with Reanalysis Tiger Team on specification of lightning NOx.
- Developed QA/QC techniques for *GOES* satellite surface skin temperature products for removing cloud contaminated pixels using cloud albedo products.
- Served on Program Committee and attended – *Meteorology and Air Quality Conference at the University Of California Davis Sept 2015.*
- Presenting satellite skin temperature moisture nudging in Pleim-Xiu scheme in WRF at the American Meteorological Society Meeting in New Orleans January 2016.

Project: Contribute to Oil and Natural Gas (ONG) Tiger Team

PI: R. Bradley Pierce

Organization: NOAA NESDIS

- This project focuses on development of high spatial resolution OMI NO_2 retrievals by using VIIRS day night band (DNB) composite radiances to spatially refine OMI NO_2 retrievals, evaluation of Western Region Air Partnership and US EPA NEI 2011 emission inventories using OMI NO_2 columns, and conducting air quality model sensitivity studies to characterize the impact of ONG emissions on western US Air Quality.

  This year's effort initially focused on validation of the spatially enhanced OMI NO_2 retrievals using in situ airborne NO_2 profiles collected during the 2014 Front Range DISCOVER-AQ field mission. DISCOVER-AQ provided 220 column integrated in situ NO_2 profiles for validating the OMI Standard, and OMI Enhanced NO_2 retrievals. However, out of 220 profiles there were only 10 coincidences which were near the center of the OMI Standard pixel and within +/- 3 hours which had cloud radiance fractions of less than 0.3. Based on this limited sample, the OMI Enhanced retrieval shows somewhat lower correlations with the in situ NO_2 columns (0.66 vs 0.80), but has lower biases (1.44 vs 2.16 $x10^{15}$ mol/cm^2) and similar RMS errors (5.6 vs 5.9 $x10^{15}$ mol/cm^2). When all profiles are considered, histograms of the airborne NO_2 columns show a long tail towards higher values from profiles over the Denver metropolitan area which is better captured by the OMI Enhanced retrieval than the OMI Standard retrieval, demonstrating the value of the spatially enhanced OMI NO_2 retrieval for metropolitan areas.

The utility of using the OMI spatially enhanced NO_2 retrieval to understand urban NO_2 distributions was demonstrated by working with the Wisconsin Department of Natural Resources (WDNR) and LADCO to utilize the spatially enhanced OMI NO_2 columns to look at NO_2 emissions in the Chicago area. Comparisons between OMI Standard and Spatially Enhanced NO_2 column retrievals and 4km WRF-CHEM NO_2 columns over Chicago during July 2011 shows that the WRF-CHEM NO_2 columns are high by a factor of 2 when the NEI 2011 emission inventory is used. This leads to excessive ozone titration within a lake breeze driven plume of high NO_2 column along the western shore of Lake Michigan within the WRF-CHEM simulations. Sensitivity experiments including 50 percent reductions in Chicago, Milwaukee, and Green Bay NO emissions show overall improvement in the correlation with AIRNow and reductions in the biases along western Lake Michigan but are still not able to capture the high surface ozone observed North of Milwaukee on July 17, 2011. Results of these experiments were presented to LADCO during their July 2015 Project Team conference call.

Based on discussions at the June 2-4, 2015 St. Louis AQAST meeting (AQAST9), we are working with WDNR (Angie Dickens) and LADCO (Rob Kaleel) in preparing a white paper to submit to NASA HQ proposing a small to medium size ground/airborne/satellite campaign during the summer 2017 with primary science objectives focusing on characterizing the recirculation, aging, and mixing of the Chicago and Milwaukee urban plumes as they move over Lake Michigan and their impact on surface ozone. The overall objectives of the study are to better characterize ozone formation chemistry, emissions, meteorology and transport along the Great Lakes' shorelines with the ultimate goal of improving photochemical modeling along the lakeshores. Specifically, this mission will focus on:

1) Constraining the factors controlling ozone chemistry, including:
   - NOx versus VOC limitations on ozone formation.
   - Constraints on NOx emissions sources (such as urban, mobile and marine shipping sources).
   - Chemical aging of urban plumes and how this affects ozone formation.
   - Losses of ozone and precursors via deposition.
2) Understanding controls on meteorology and transport of emissions affecting ozone episode development, including:
   - Better constraints on the lake breeze, including its vertical structure, height of the boundary layer, extent of inland penetration, and conditions leading to the presence/absence and different types and locations of lake breezes.
   - Determine the relative importance of local vs regional emissions transported from upwind areas via synoptic circulation (e.g., from the Ohio River Valley and other regions).
3) Improve understanding of sources of model forecast errors (marine boundary layer structure, interplay between synoptic and lake breeze fronts, coastal impacts, over lake processing

A key component of the proposed field study would be NASA airborne remote sensing, including Geostationary Trace Gas and Aerosol Sensor Optimization (GeoTASO) to conduct NO_2 emission mapping, characterize lake driven transport, and constrain ozone photochemistry through observed HCHO/ NO_2 ratios, and High Spectral Resolution Lidar (HSRL) aerosol and Differential Absorption Lidar (DIAL) ozone retrievals to characterize O_3 vertical structure, lake driven transport, overlake abundances, and PBL dynamics. Plans for the Great Lakes Ozone Study were presented to LADCO during their November 2015 Project Team conference call.

Project: Improving Operational Regional Air Quality Forecasting Performance through Emissions Correction Using NASA Satellite Data and Surface Measurements

PI: Armistead Russell

Organization: Georgia Institute of Technology

- This project uses emission correction methods that incorporate OMI and MODIS retrievals and surface measurements to improve the operational regional air quality forecasting performance. The project is intended to provide more accurate and targeted information for dynamic air quality management.

  During 2015, the Georgia Tech team made operational an advanced version of HiRes2, a model-based air quality forecasting system. The new system directly integrates observations to continually update emissions inventories for better performance of air quality forecasting.

  One of the new features of HiRes2 is the ability to forecast the impacts of mobile sources and power plants on ozone and particulate matter. These forecasts are now available along with the ozone and PM forecasts. The forecasting capability can support dynamic air quality management, for example in connection with an electricity generation dispatch system to reduce pollutant exposure as featured in a publication in the Proceedings of the National Academy of Science (Kerl et al., PNAS, 2015).

  HiRes2 was also used to forecast the potential impacts of prescribed burning in Georgia. While not well recognized, prescribed burning in the Southeast leads to a greater acreage of burning than wildfires in the West, and health studies consistently show high impacts of biomass burning. Prescribed burning is one source that is more prone to dynamic air quality management than others as burns can be deferred to another day. A unique feature of the new forecasting approach is that it includes, weather- and ecological need-based prescribed burn forecasting, along with atmospheric dispersion and chemistry modeling. As part of this portion of the

project, satellite retrieval-based estimates of fire emissions were compared to ground-based estimates.

For both the mobile/power plant and the prescribed burning impact forecasts, we developed a public website to disseminate forecasting products on a daily basis (https://forecast.ce.gatech.edu).

In 2016 the team will continue to advance the HiRes2 forecasting system, while also using it in support of air quality management needs in the Southeast. Planned developments include further integration of satellite-based, and in situ observation-based adjustments to the emissions to improve forecast accuracy and to provide near-time assessments of emissions biases. Further potential roles of the air quality forecasting system in dynamic management opportunities will be investigated, working with our partners in the Southeast.

We also continue to evaluate model performance and advance the forecasting capabilities for use in other areas. Recently, the forecast fields were used to help our health-assessment partners assess pollutant exposure in the Southeast using a model-observation fusion approach. CDC has worked with us to use model fields for health impact assessments as well.

Project: Assessment of the Applicability of Current Worldwide Studies of Satellite Retrievals and Emissions Estimation to U.S. Air Quality Management

PI: David Streets

Organization: Argonne National Laboratory

- Over the past year, the project team finalized and published its work on using OMI NO_2 retrievals to estimate NO_x emissions from 35 major U.S. urban areas for the period of 2005-2014 with emphasis on the inclusion of information on wind speed and direction (Lu, published in ACP). The team also updated its unit-based Indian coal-fired power sector database for the period of 2012-2014 and compared the bottom-up NO_x and SO_2 emissions with the most recent OMI NO_2 and SO_2 retrieval products provided by Nick Krotkov of NASA/GSFC. The analysis by the team showed that SO_2 emissions from the Chhattisgarh and Odisha regions of India increased by ~190 percent from 2005 to 2014, in agreement with a ~200 percent increase in OMI SO_2 observations (Krotkov, published in ACPD).

- In collaboration with AQAST members, the team participated in several studies: 1) using different methods to estimate NO_x emissions from U.S. power plants with OMI retrievals (Benjamin de Foy at Saint Louis University, published in AE); 2) a quantification of NO_2 trends (2005–2013) over the U.S. using surface measurements

and improved OMI NO_2 retrievals (Lok Lamsal at NASA/GSFC, published in ACP); 3) an evaluation of NO_2 trends over five regions and 195 cities all over the world during 2005-2014 with OMI NO_2 observations (Bryan Duncan at NASA/GSFC, submitted to JGR); 4) a contribution to the success of the AURA mission using ten years of atmospheric composition data (Bryan Duncan, in preparation for BAMS); and, 5) studying the impacts of the great recession, long term trends, and weekday variations in NO_2 columns over 54 Northern American cities (Benjamin de Foy at Saint Louis University, submitted to AE).

Project: Improved Web-based Access to NASA and NOAA Airborne Data Sets in Support of Chemical Transport Model (Regional and Global) Evaluation

PI: Jim Szykman

Organization: EPA

- This Tiger Team project is designed to extend the development of an interoperable web-based infrastructure to highlight added value of NASA data for use in model evaluation, constraints on emission fields, and provide visualization capabilities to present data in a user-ready and policy relevant manner.

  The project team efforts continued to focus on increasing the overall Application Readiness Level of the underlying web-enabled infrastructure. Partner agency (EPA) resources were used to develop the new EPA RSIG 3D application in support of the overall objectives of this Tiger Team project. In 2015, additional NASA Earth Science Data sets were prototyped and tested with the RSIG system.

  The team effort continued to focus on the addition of UAH supported *GOES* satellite products for use in WRF/CMAQ/CAMx and the ability to access and visualize TF-HTAP & CCAC global model runs. Additionally, working with the CALIPSO team, level 3 screening criteria for CALIPSO extinction and AOD data products have been added to the RSIG-CALIPSO connection with the ability to apply these data screening criteria to level 2 data products at native product resolution.

  At the end of FY15, the new RSIG 3D application was released as a beta application. In the coming FY, we will be working with the AQ user community to evaluate the new functionally added to the RSIG 3D application under this Tiger Team project.

Project: Optimizing Air Quality Forecasts with NASA Observations and Economic Data

PI: Anne M. Thompson

Organization: NASA-Goddard Space Flight Center & Pennsylvania State University

- A new method for western AQ ozone forecasts has been developed with PSU graduate student Nikolay Balashov. Based on self-organizing maps (SOM), several variants were developed and analyzed compared to surface ozone data at stations throughout the San Joaquin Valley. Work was presented as a Poster at the IWAQFR (International Workshop on Air Quality Forecasting) held in College Park, MD, in September, and sponsored by NOAA/ARL.
- Worked with Bryan Duncan as co-author on paper submitted to *JGR* entitled: "A space-based, high-resolution view of notable changes in urban NO_x pollution around the world (2005 - 2014)." Participant in related press conference at Fall AGU 2015 with Bryan and Russ Dickerson.
- Tiger Team Accomplishments. Changes in methane observed from TES between 2006-2008 vs 2009-2011 demonstrate significant increases (5-10 percent) over ONG regions, especially over Texas Eagle Ford and Permian Shale operations and over the North Dakota Bakken. New method of looking at TES NH_3 and enhancement ratios better identifies whether methane increases in those areas are contaminated with changes in agricultural activity.

Abbreviations and Acronyms:

AAAS: American Association for the Advancement of Science
ACOM: Atmospheric Chemistry Observations & Modeling
AMS: American Meteorological Society
AOD: Aerosol Optical Depth
AQ: Air Quality
AQAST: Air Quality Applied Sciences Team
ARL: Application Readiness Level
ASCENDS: Active Sensing of CO_2 Emissions over Nights, Days, and Seasons
ASDP: AirNow Satellite Data Processor
ASTMH: American Society of Tropical Medicine and Hygiene
AWMA: Air and Waste Management Association
BCRS: Beach Conditions Reporting System
BVOC: Biogenic Volatile Organic Compounds
CALIPSO: Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CASTNET: Clean Air Status and Trends Network
CCHHG: Climate Change and Human Health Working Group
CDC: Centers for Disease Control and Prevention
CEMS: Continuous Emission Monitoring System

CMAQ: Community Mulit-scale Air Quality
CONUS: Contiguous United States
CoP: Community of Practice
CyanoHAB: Cyanobacterial harmful algal bloom
CTM: Chemical Transport Models
DISCOVER-AQ: Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality
EE: Exceptional Event
EOS: Earth Observing System
EPA: Environmental Protection Agency
EPHT: Environmental Public Health Tracking
ESD: Earth Science Division
EWS: Early Warning System
FAMWEB: Fire and Aviation Management Web
FRAPPÉ: Front Range Air Pollution and Photochemistry Éxperiment
GEO: Group on Earth Observations
GEO-CAPE: GEOstationary Coastal and Air Pollution Events
GEOS-Chem: Goddard Earth Observing System–Chemistry
GFDL: Geophysical Fluid Dynamics Laboratory
GIBS: Global Imagery Browse Services
GISS: Goddard Institute for Space Studies
GOCI: Geostationary Ocean Color Imager
GOES: Geostationary Operational Environmental Satellite
GPM: Global Precipitation Measurement
GSFC: Goddard Space Flight Center
GSI: Gridpoint Statistical Interpolation
HMS: Hazard Mapping System
HyspIRI: Hyperspectral Infrared Imager
IASI: Infrared Atmospheric Sounding Interferometer
IMPROVE: Interagency Monitoring of Protected Visual Environments
LADCO: Lake Michigan Air Directors Consortium
LANCE: Land Atmosphere Near real-time Capability for EOS
LDAS: Land Data Assimilation System
MBG: Missouri Botanical Garden
MISR: Multi-angle Imaging SpectroRadiometer
MM5: Mesoscale Meteorological Model Version 5
MODIS: Moderate Resolution Imaging Spectroradiometer
MOPITT: Measurements of Pollution in the Troposphere
MOU: Memorandum of Understanding
MSFC: Marshall Space Flight Center
NAAPS: Navy Aerosol Analysis and Prediction System
NASA: National Aeronautics and Space Administration
NCAR: National Center for Atmospheric Research
NDHS: Net Daily Heat Stress

NEI: National Emissions Inventory
NESDIS: National Environmental Satellite, Data, and Information Service
NLDAS: North American Land Data Assimilation System
NOAA: National Oceanic and Atmospheric Administration
NRT: Near Real Time
OCO-2: Orbiting Carbon Observatory-2
OMI: Ozone Monitoring Instrument
OMPS: Ozone Mapping Profiler Suite
ONG: Oil and Natural Gas
PACE: Pre-Aerosol, Clouds, and Ocean Ecosystem
PAR: Photosynthetic Active Radiation
PI: Principal Investigator
$PM_{2.5}$: Fine particulate matter
RAQMS: Real-time Air Quality Modeling System
ROSES: Research Opportunities in Space and Earth Sciences
RSIG: Remote Sensing Information Gateway
S-NPP: Suomi National Polar-orbiting Partnership
SBA: Societal Benefit Area
SEAC4RS: Studies of Emissions, Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys
SIP: State Implementation Plan
SMAP: Soil Moisture Active Passive
SOA: Secondary Organic Aerosol
SPoRT: Short-term Prediction Research and Transition
STAR: The Center for Satellite Applications and Research
TCEQ: Texas Commission on Environmental Quality
TEMPO: Tropospheric Emissions: Monitoring of Pollution
TES: Tropospheric Emission Spectrometer
TRMM: Tropical Rainfall Measuring Mission
UAH: University of Alabama in Huntsville
USFS: United States Forest Service
USGCRP: U.S. Global Change Research Program
USGEO: U.S. Group on Earth Observations
USGS: United States Geological Survey
UVB: Ultraviolet B
VIIRS: Visible Infrared Imaging Radiometer Suite
WDNR: Wisconsin Department of Natural Resources
WHO: World Health Organization
WMO: World Meteorological Organization
WNV: West Nile Virus
WRF: Weather Research and Forecasting
WRF-AERMOD: Weather Research and Forecasting–American Meteorological Society/Environmental Protection Agency Regulatory Model
WRF-Chem: Weather Research and Forecasting–Chemistry

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